1. Introduction

Tissue Engineering, the science and engineering of creating functional tissues and organs for transplantation, integrates a variety of scientific and engineering disciplines to produce physiologic “replacement parts” for the development of viable substitutes which restore, maintain or improve the function of human tissues. In recent Multi-Agency Tissue Engineering Science (MATES) Interagency Working Group [1], the field of tissue engineering has been broadened and redefined as “the use of physical, chemical, biological, and engineering processes to control and direct the aggregate behavior of cells”. In the success of tissue engineering, three-dimensional (3D) scaffolds play important roles as extra-cellular matrices onto which cells can attach, grow, and form new tissues. Modeling, design and fabrication of tissue scaffolds to meet multiple biological and biophysical requirements is always a challenge in regenerative tissue engineering. This is particularly true when designing load bearing scaffolds for bone and cartilage tissue application. In general, this type of scaffolds usually have intricate architecture, porosity, pore size and shape, and interconnectivity in order to provide the needed structural integrity, strength, transport, and ideal micro-environment for cell and tissue ingrowth. In addition, thus designed scaffolds often can only be fabricated through advanced manufacturing techniques, such as solid freeform fabrication (SFF) to manufacture complex structural architectures.

2. Introduction

Advances in computer-aided technologies and its application to tissue Engineering created a new field of BioCAD for Tissue Science and Engineering. This interdisciplinary field integrates computer-aided design, imaging process, manufacturing, and solid freeform fabrication to model, design, simulate, and manufacture biological tissue and organ substitutes. BioCAD in tissue engineering is broadly classified into the
following three major applications [2-5]: 1) computer-aided tissue modeling, including 3D anatomic visualization, 3D reconstruction, computer-aided design (CAD) of tissue models and bio-physical modeling for surgical planning and simulation; 2) computer-aided tissue scaffold informatics and biomimetics (The study of the structure and function of biological systems as models for the design and engineering of biomaterials), including computer-aided tissue classification and application for tissue identification and characterization at different tissue hierarchical levels, biomimetic design under multi-constraints, and multi-scale modeling of biological systems; and 3) bio-manufacturing for tissue and organ regeneration, including computer-aided manufacturing of tissue scaffolds, biomaterial manufacturing of tissue constructs, bio-blueprint modeling for 3D cell and organ printing. An overview of BioCAD in Tissue Science and Engineering is outlined in Figure 1.

BioCAD allows exploring many novel approaches in modeling, design, and fabrication of complex tissue scaffolds that have enhanced functionality and improved interactions with cells. For example, BioCAD can apply biomimetic design approach to introduce multiple biological and biophysical requirements into the scaffold design. BioCAD also allows the integration both biomimetic and non-biomimetic features into the scaffold modeling database to form high fidelity and smart scaffolds. Biomimetic features can be based upon real anatomical data regenerated from CT/MRI images, or can be created purely within a CAD environment, such as channels and porous structures. Non-biomimetic feature do not imitate nature but can be designed as drug storage chambers, mechanical elements, and attachment interfaces for tubes, sensors, electronics, and other devices for various regenerative tissue engineering applications. Central to BioCAD is its ability to represent pertinent tissue biological, biomechanical, and biochemical information as a computational, or in most cases, a CAD-based, bio-tissue informatics model. This model can be used as a center repository to interface design, simulation and manufacturing of tissue substitutes. This computational scaffold informatics model can advance tissue engineering from its segmental disciplinary and empirical laboratory based study to an integrative empirical, laboratory and computer modeling and simulation based interdisciplinary research.

References


